SECTION 3 - WATER QUALITY DATA ASSESSMENT

3.0 INTRODUCTION

This section provides a description of the source water quality monitoring data obtained from 1993 onwards. The competing contaminants that interfere with arsenic removal were identified and the levels at which these contaminants are of concern are discussed. Based on this information, water quality profile groups were developed that can assist in technology evaluation, selection and treatment efficiency determination. The impacted POEs identified in Section 2 were assigned a water quality profile designation. Additional monitoring is recommended at other sites with insufficient data in order to develop profiles for these sites.

3.1 SOURCE WATER DATA

Source water data was obtained from ADEQ wells listed in the hydrological assessment database and the USGS groundwater database. The source water wells consisted of drinking water wells and non-drinking water wells located within a radius of ½ mile from an arsenic impacted POE. Information obtained from the ADEQ drinking water database was also used to perform this assessment.

3.2 WATER QUALITY IMPACTS ON ARSENIC REMOVAL

Arsenic removal in drinking water systems is affected by other water quality parameters, such as silica, phosphorus, pH, fluoride, sulfate, chloride, TDS, iron and manganese. The impacts of each of these parameters on arsenic removal is described below.

3.2.1 Silica

Silica is the most significant competing anion that interferes with arsenic removal in an arsenic removal system that utilizes adsorption. Silica, reported as SiO_2 in analytical results, is normally present in drinking water as silicic acid (H_4SiO_4) and silicate ion ($H_3SiO_3^-$). The equilibrium dissociation constant (pK) is approximately 9 between these two species. The neutrally charged silica species are dominant below pH 9, while the negatively charged silicate ions are predominant above pH 9. However, even between the pH range of 7 to 9, significant quantities of $H_3SiO_3^-$ are present, particularly in relationship to the concentration of arsenic in drinking water. Silica levels are generally three to four magnitudes greater than the levels of arsenic in drinking water, so the potential for interferences from silica at lower pH values also exists. Additionally, the neutrally charged silicic acid particles may exist in colloidal and polymerized form and develop a slight surface charge under certain conditions. This may even cause neutrally charged silicic acid to adsorb to iron and alumina based systems. Silica (SiO_2), at levels of even 10-20 mg/L, can cause an impact on adsorption processes.

Silica levels greater than 20 mg/L were considered high for developing water quality profiles in the this project. Fe-AA cannot be used as a treatment technology for arsenic removal if silica is present in concentrations greater than 50 mg/L in source water.

3.2.2 pH and Alkalinity

pH and alkalinity are important considerations in the design of arsenic treatment systems. They can impact chemical feed parameters for technologies requiring pH adjustment. Most systems will operate more efficiently at stable pH values at or below 7.0. As pH levels rise above 8.0, the media loses its positive charge and more silica ions are present, both significantly reducing adsorption capacity. Since pH adjustment may be required for many of the treatment technologies, pH is considered an important parameter in arsenic treatment. The following pH classification was used for assessing groundwater treatment needs:

C Low pH (<7.0)
C Moderate pH (7.0 - 8.0)
C High pH (>8.0)

3.2.3 Fluoride

Fluoride will be removed with arsenic in Fe-AA processes. Fluoride significantly impacts arsenic removal in Fe-AA systems as it competes for the adsorption sites along with arsenic. Based on limited existing data, the following range of fluoride levels was used to sub-classify water at DEQ wells:

C Low (<1 mg/L)
C Moderate ($1 - <2 mg/L)
C High ($2mg/L)

3.2.4 Phosphorus

Trace levels of phosphorus (0.1-0.2 mg/L), reported as total phosphorus, can significantly impact adsorption using granular iron media. This is because phosphorus chemistry and ionic charges are similar to those of arsenate compounds in the pH ranges found in drinking water. From testing performed in Germany, influent phosphate levels between 0.30 and 0.78 mg/L had a significant impact on arsenic removal capacity of GFH. As the molecular ratio of phosphorus to arsenic increased from <1:1 to 10:1, the arsenic adsorptive capacity decreased by over 80%. Similar test results from Fallon, NV indicated that phosphorus levels of 0.2 mg/L reduced treatment capacity by over 50%. Where phosphorus levels are greater than 0.2 mg/L, granular iron media will not be an acceptable treatment technology. Monitoring of phosphorus concentrations in granular iron media treatment systems is required to determine arsenic removal capacity.

3.2.5 Sulfate

Moderate levels of sulfate may impact the run length of adsorption columns before regeneration. Sulfate peaking can occur, but it is generally insignificant in Fe-AA or granular iron media systems. Fe-AA processes are not affected by sulfate interference unless the levels exceed 200 mg/L. Based on previous pilot tests, sulfate levels were sub-classified as:

- Low (<100 mg/L)
- Moderate (100 - 200 mg/L)
- High (>200 mg/L)

3.2.6 Total Dissolved Solids

Uptake of small amounts of inorganic constituents that comprise TDS may cause a reduction in arsenic treatment capacity in adsorption processes. Although constituents such as chlorides, sulfates, bicarbonates may not individually pose any significant impact to adsorption systems, when present in high concentrations (>750 mg/L), they may be sorbed to the arsenic removal media due to the principles of mass action. Even though the selectivity of Fe-AA and granular iron media is low for these substances, when large masses of these constituents are present they will likely pose interferences with arsenic removal, even if only small percentages of TDS are removed.

3.2.7 Iron and Manganese

Unlike other constituents described above, iron and manganese do not compete for exchange and adsorption sites within the treatment media. Arsenate may attach to oxidized iron and manganese and affect removal efficiency and/or plug IX and activated alumina columns (if particle sizes are large enough). High levels of these constituents, 0.05 mg/L Mn and 0.5 mg/L of Fe, may impact adsorption systems, particularly if sufficient oxidation occurs before the treatment system. At these levels, the utility should consider iron and manganese levels in treatment process selection. If oxidation is not sufficient, then reduced species of iron and manganese in the dissolved form will pass through the contactor and not affect removal efficiency. If column plugging or reduced run lengths are observed in Fe-AA or Granular iron media contactors (prior to arsenic breakthrough), iron and manganese levels should be monitored.

3.3 COMPETING CONTAMINANT DATA

Table 3.1 shows a summary of competing contaminant data for arsenic removal for small groundwater systems serving less than 10,000 persons. Based on this data, water quality profile groups were developed. Eight primary categories were developed based on arsenic, pH and fluoride data as shown in Table 3.2. Additional flags for chloride, silica, sulfate, TDS, phosphorus, iron and manganese were also included. The classification was reported as NA (not available) if either arsenic, pH or fluoride data was found missing. Water quality profile classification on a POE basis is shown in Table 3.1. It was observed that from a total of 465 affected POEs, water quality data was available for only 260 POEs. Additional sampling to further identify water quality profiles for the remaining 205 affected POEs needs to be performed. The impacted POEs for which missing water quality data was identified are shown in Table 3.3.

Table 3.2 - Water Quality Profile Groups

GROUP	CLASSIFICATION
1A	Arsenic <= 20 ppb, pH <= 8, Fluoride <= 2 mg/L
1B	Arsenic <= 20 ppb, pH > 8, Fluoride <= 2 mg/L
2A	Arsenic <= 20 ppb, pH <= 8, Fluoride > 2 mg/L
2B	Arsenic <= 20 ppb, pH > 8, Fluoride > 2 mg/L
3A	Arsenic > 20 ppb, pH <= 8, Fluoride <= 2 mg/L
3B	Arsenic > 20 ppb, pH > 8, Fluoride <= 2 mg/L
4A	Arsenic > 20 ppb, pH <= 8, Fluoride > 2 mg/L
4B	Arsenic > 20 ppb, pH > 8, Fluoride >2 mg/L

Note: To indicate interference of other source water contaminants, flags were added to the groups for the following criteria:

C Silica > 50 mg/L
C Chloride >200 mg/L
C Sulfate >200 mg/L
C TDS > 750 mg/L
• Phosphorus > 0.2 mg/L
• Iron > 0.5 mg/L and manganese > 0.05 mg/L

Fe-AA treatment is impacted by silica concentrations > 50 mg/L and/or fluoride > 2 mg/L. The impacted POEs for these systems are shown in Table 3.4. Similarly, granular iron media treatment is impacted by pH > 8.0 and/or phosphorus concentrations > 0.2 mg/L. The impacted POEs for these systems are shown in Table 3.5. As shown in Tables 3.4 and 3.5, 13 POEs were affected by source water quality that affects Fe-AA treatment and 20 POEs were affected by source water quality that affects Granular iron media treatment. The possibility of additional systems with similar interferences from competing contaminants should be investigated after additional water quality monitoring is performed.

Table 3.4 - Summary of Systems with Water Problems that affect Fe-AA treatment

System ID	POE ID	POE flow (gpm)	POE flow (mgd)	Arsenic conc (ppb)	Fluoride (mg/L)	Silica (mg/L)
01004	755	290	0.418	0.011	2.9	10
07305	001	0	0.000	0.02	3.6	20
07411	001	800	1.152	0.023	5.5	34.42
08035	001	0	0.000	0.017	0.59	53.75
08038	002	95	0.137	0.015	0.8	50.06
13025	008	0	0.000	0.022	0.3	69
13081	001	228	0.328	0.034	0.4	68
13106	001	55	0.079	0.027	0.3	75
13106	006	430	0.619	0.12	0.3	69
13116	001	0	0.000	0.017	0.3	75
14361	001	160	0.230	0.018	7	42
14363	001	240	0.346	0.026	8	43
14363	002	150	0.216	0.034	8	43

Table 3.5 - Summary of Systems with Water Quality Problems that affect Granular Iron Media treatment

System ID	POE ID	POE flow (gpm)	POE flow (mgd)	Arsenic conc. (ppb)	pH	Phosphorus (mg/L)
01004	755	290	0.418	0.011	8.1	
02061	001	2000	2.880	0.02	8.4	
03002	002	350	0.504	0.013	8.2	0.31
03362	001	62.5	0.090	0.0185	8.1	0.03
04003	001	1462.47	2.106	0.0345	8.04	0.04
05002	001	500	0.720	0.0221	9.49	
06004	001	0	0.000	0.026	8.19	0.02
06006	001	83.3	0.120	0.034	8.6	
07114	001	40	0.058	0.0185	7.3	0.25
07411	001	800	1.152	0.023	8.36	
08068	001	444	0.639	0.057	9.08	
09034	001	60	0.086	0.016	8.4	
11018	002	0	0.000	0.017	8.36	0.03
13141	002	9.03	0.013	0.014	8.26	
13351	001	20	0.029	0.012	7.43	0.44
14322	001	41.7	0.060	0.013	7.32	0.24
14361	001	160	0.230	0.018	8.6	
14363	001	240	0.346	0.026	8.1	
14363	002	150	0.216	0.034	8.1	
14442	001	72.9	0.105	0.031	8.27	

It is to be noted that due to limited data on phosphorus, iron and manganese, these parameters were not used in the water quality profile classification.

The water quality profile groups were classified based on system size into three categories. A matrix of water quality profile groups and system sizes is shown in Table 3.6. It was observed that 129 POEs had water quality profiles that matched low arsenic values (As <20 ppb) and 131 POEs had water quality profiles that matched high arsenic values (As >20 ppb). For systems with low arsenic water quality profiles, 60% of the POEs belonged to 1A category, 25% to 1B category, 8% to 2A category and 7% to 2B category. For systems with high arsenic water quality profiles, 60% of the POEs belonged 3A category, 12% to 3B category, 11% to 4A category and 17% to 4B category respectively. Water quality profile breakdown for low arsenic systems (As < 20 ppb) and high arsenic systems (As > 20 ppb) are shown in Figures 3.1 and 3.2 respectively. It appears that most of the high and low arsenic systems have a water quality profile with pH levels below 8 and fluoride levels <2 mg/L, making the water more amenable to adsorption.

Figure 3.1: Water Quality Profiles for Low Arsenic Systems (<20 ppb As)

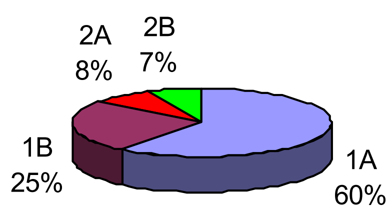
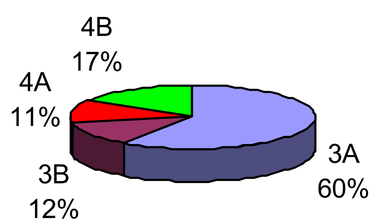


Figure 3.2: Water Quality Profiles for High Arsenic Systems (>20 ppb As)



3.4 RECOMMENDATIONS

Additional sampling is recommended to obtain water quality data for silica, phosphorus, iron and manganese at the impacted POEs to further develop the water quality profiles presented herein. Due to limited data on phosphorus, iron and manganese, they were not used in the profiles. In general, iron and manganese levels are typically low in Arizona. Before finalizing this report, ADEQ's groundwater database will be evaluated for iron and manganese data. Based on the evaluations, a monitoring program for iron, manganese, and phosphorus will be developed.